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MAINTAINING AMERICA'S TECHNOLOGICAL SUPERIORITY

THE THREAT OF RUSSIAN COMPETITION

You have heard during the morning session several speakers pointing out the growing need in this country for scientists and engineers not only for programs involving national security, but also for continually advancing the standard of living of the people of this nation. I have been asked to discuss the comparable situation in the Soviet Union. I do not do this in order to provide a spur to our own scientific development because I do not believe such a spur should be required. Increased scientific improvements in the development of scientific and engineering manpower can be justified for its own sake and should not require justification on the basis of Russian threat. However, I do feel it may be useful to briefly outline the situation in Russia since it may provide ideas which can assist us in our own endeavors.

I should like today to cover four main topics. First of all, in order to provide background I believe a brief coverage of the qualitative aspects of the Soviet scientific and engineering manpower might be useful. However, numbers can be very deceiving and therefore it is important to go beyond these figures and try and get some feeling for the quality of the manpower available to the Soviets. In this connection, I will try and briefly

outline some of the information we have on the Soviet educational system. Then I shall discuss the methods by which the Soviets select and utilize their scientific manpower and finally give some ~~of the~~ examples of their accomplishments.

Soviet Scientific-Technical Manpower Force

Today the United States and the Soviet Union each has a scientific-technical manpower force of about 1.2 million. In research and teaching the Soviet Union has a force only about 2/3ds that of the United States (175,000 vs 265,000). In research alone, they have only about half the number we have (120,000 vs about 210,000). But each year, though we turn out 10% more college graduates than they, they graduate many more in science and engineering than we do. For example, in 1955, 60% of Soviet full-time students graduated in scientific-technical fields as compared to only about 25% in the United States. In engineering alone, the Soviet Union graduated twice as many as did the United States.

Chart 1, Graduates per Year in All Scientific Fields, shows the steady increase in both countries in numbers of graduates in all science fields from 1930 to 1960. In 1930 both countries were almost equal, each graduating about 36,000 science students. The 1933 drop to 19,000 in the Soviet curve resulted from a lengthening of courses. The rise in 1935 (in the Soviet curve) reflects the expanded enrollments in 1930/32. Both the United States and Soviet curves show wartime losses from about 1942/43 to 1945. Soviet losses were greater than ours. They dropped to about 22,000

in 1945 compared to about 39,000 in the United States. Rapid post-war increases are shown for both countries. We climbed faster and farther and reached a peak of about 134,000 science graduates in 1950, largely under the "GI Bill", and then started declining. They climbed less spectacularly, but note that the Soviet curve did not go into a decline. That curve is still rising. In June 1954, Soviet science graduates outnumbered ours by about 36,000. It is estimated that in 1960 the Soviet Union will graduate about 155,000 science students compared to about 126,000 in the United States. These estimates for future graduates are of course somewhat uncertain but they do take into account all factors which we believe should be considered including the fact that the total available manpower in the ages 16 to 20 will be in the next five years below normal because of wartime deceleration of the birthrate.

One can make the same type of analysis for specific scientific fields. For example, the curves for graduates in the physical sciences and engineering are very similar in shape to those shown for the total of all scientific fields. In 1950, the peak U. S. year, we graduated almost 80,000 as compared with 40,000 Soviet students in these fields. However, in 1955 the situation was reversed and the Soviets graduated 75,000 as compared to some 56,000 in this country. We estimate that the present disparity will continue at perhaps a slightly reduced level into the future unless radical steps are taken to change the ~~future~~ picture. If these trends continue, it is apparent that soon

the Soviets will have a decided advantage in numbers of scientific-technical personnel. Continued expansion of their manpower reservoir is assured by the Soviet educational system.

Soviet Educational System

Since the character of the educational system ~~will probably be the~~ is a most important determining factor in the quality of ~~the~~ Soviet scientific resources, I should like to discuss some of its most important features. First of all, the system is designed mainly to train scientists, technicians and skilled labor for the nation's economy. Even the elementary schools stress science. There are no electives and therefore every Soviet student has taken five years of physics, five years of biology, four years of chemistry, and 10 years of mathematics by the time he has finished high school. With the exception of mathematics the significant factor may not be the number of years that a student has taken these subjects but rather that every Soviet student has been exposed to these subjects and is therefore in a position if sufficiently smart to go forward and pursue scientific courses at a higher level. This is particularly true of mathematics which is ~~not~~ in this day essential to almost any advanced scientific endeavor. By contrast, ~~only~~ less than 10% of American high school graduates, have taken as much as a year of physics and chemistry and even fewer ~~any~~ only advanced mathematics. It is this broad background at the high school level which provides the Soviets with the basic material

to funnel into the top of the scientific hopper out of which will eventually come the scientific manpower to fulfill the needs of the Soviet economy. Before leaving the subject of high school education, it might be useful to investigate the quality of training which a student receives. An evaluation of Soviet high school text books for physics courses shows that the coverage is not as up-to-date as that presented in U.S. high school texts but the range of materials presented is broader. There is greater emphasis on factual matter than on principles. Perhaps one of the best ways of evaluating the quality of the student is to look at the examinations which he has to pass in order to graduate and proceed on to higher education. These exams are for a large part oral exams. The student is given in advance a large number of different topics which will be covered and then he draws by lot a topic on which he will have to answer questions. This type of approach does call for an ability on the part of the student to be able to think on his feet and express himself, but does have the weakness that the number of possible questions is limited and advance cramming could produce significant improvement. It is interesting to note that the same questions are used throughout the Soviet Union which certainly will lead to a degree of uniformity in the educational standards. We have examined a number of these sets of questions and indeed I have a copy here if anybody would like to look at them. I believe

there was also a set of questions published earlier this week in the NEW YORK TIMES. THEY ARE COMPREHENSIVE AND DIFFICULT. It may be interesting that Some of the harder questions in this set were recently used at a top-notch American university as examinations given to college students commencing their graduate work. These first year graduate students did not find the questions particularly easy and in fact did about as well on these questions as they did on the normal exams given them on the commencement of graduate work.

After completing high school, the better SOVIET students enter higher educational institutions of which there are three WHICH OFFER SCIENTIFIC-TECHNICAL TRAINING main types;

(a) Engineering and technical colleges offer 4-6 year courses in specialized fields such as machine building, construction, and agricultural mechanization. These colleges prepare engineers and specialists for particular industries.

(b) Polytechnic institutes offer 5½ year courses in broader engineering fields such as civil, electrical, and metallurgical engineering. Students graduate as production engineers and enter the economy.

(c) Universities offer 5-[illegible] year courses in fundamental sciences. Graduates enter research or teaching--the better graduates are directed to research.

Almost half a million students enter these Soviet colleges each year. They spend, as indicated, 4-6 years in a

rigorous course of study. Discipline is strict. Attendance at lecture and laboratory sessions is compulsory. As many as 10 comprehensive examinations are given each year. Those who fail are weeded out. Those who do well are rewarded by increased stipends.

While in college students spend more than 80% of their time on technical subjects. The next chart shows you the scientific subjects studied and the number of hours allocated to each subject for physics majors at Kharkov State University, one of the better Soviet institutions. Students spend more than 3500 hours out of a total of 4500 hours over a 4½ year period

and in addition spend another 6 months preparing a thesis.

studying scientific subjects. I believe an inspection of the courses listed indicates that this material is at least on a par with that presented at the better universities in this country. Similar studies have been conducted for other institutions such as the Bauman Higher Technical School in Moscow which is an engineering institute. One of the impressive facts about Bauman is that all of its engineering students take physics courses which correspond in level with those taken by physics majors in this country and which are rarely taken by engineering students here. Every Bauman graduate has a training in physics corresponding to a stiff physics under-graduate minor in the US.

Quality of training in the Soviet Union in general compares favorably with that in the United States. As competition for entrance to universities and colleges is very keen, standards

are kept high. University faculties are organized so that each department is quite small and teaching often can be done through informal contact between students and staff. For example, the overall ratio of students to teachers in Soviet colleges was 10.5 to 1 in 1950 compared to about 14 to 1 in the U.S. The Soviet ratio was up to 12.6 to 1 in 1954. The ratio varies from school to school, of course, and the Soviets don't always compare so favorably. For example, at Bauman the student-teacher ratio is 11.3 to 1 compared to 5.8 to 1 at MIT and about 2.7 to 1 at CalTech. A weakness of the Soviet system is that training is often highly specialized and college graduates therefore frequently have a competence only in narrow specialty fields. Such specialization tends to create a narrowness of outlook and may well reduce the Soviet scientist's chances of producing original scientific work. Even at the college level, textbooks tend to be encyclopedic in presenting masses of factual material while emphasis on basic principles is limited. Everywhere there is emphasis on acquiring knowledge rather than understanding. Many U.S. experts feel that such "spoonfeeding" will inevitably limit independent inquiry and indeed top Soviet scientists have frequently complained about the lack of ability for graduates to carry on independent original research. In fact, it is possible that this may be the "Achilles Heel" of the Soviet educational system. There seems no question that they are capable of turning out large numbers of competent scientists capable of carrying out an orderly development program but their

educational and political systems together may work to prevent the development of the original imaginative thinkers who can take the quantum jumps required for major scientific advances.

Utilization of Scientific and Engineering Manpower

As the scientific profession in the Soviet Union is a highly honored and well paid one, the majority of Soviet students wish to prepare themselves for a scientific career. What institute a student attends and what course of study he pursues is largely a matter of state selection. Instead of depending upon individual preference or public appeal to influence the high school graduate's choice of a "major", the Soviets use several effective methods to funnel students into disciplines in accordance with the needs of the State:

(1) They use, of course, propaganda appeals, much as we do, stressing monetary and prestige factors, and in addition point out that it is the Soviet student's duty to prepare himself for usefulness in achieving socialist supremacy.

(2) Another very potent method of channeling students into desired fields is the threat of military draft. Students who enroll at particular specialized schools or in certain courses are given total draft exemptions or continuing deferments. For example, during the war a law was passed listing some 85 technical colleges whose students would be totally exempt from military draft as long as they successfully continued their studies in engineering and technical fields--fields in which there were definite needs. The law still remains in force today.

(3) Also, each college and university has a quota system. There are always more applicants than vacancies in scientific and technical fields. When shortages of specialists are anticipated, quotas are raised thereby admitting larger numbers of people.

(4) Finally, scholarships and stipends serve to channel students into desired study areas. Scientific or engineering students receive more rubles per month than do their fellows who study, say, history. As State needs change, of course, so also does the amount of stipend in a given subject field.

A quarter of a million students each year successfully complete their studies and graduate from college in the Soviet Union. Here again, the State steps in--graduates are assigned to jobs in the economy. Though some graduates may occasionally use outside influence or political "pull" to get desired assignments, more students consider it just that they work wherever the State assigns them. After all, they reason, the State paid for their education and training and therefore they are obligated to repay the State by their work. The best students usually want to go into research and do so. Once assigned a graduate has little opportunity for transfer. The engineer or scientist must remain in his assigned place for at least three years. Hence it is that 80% of Soviet science graduates are actually employed in scientific fields while only 60% of our science graduates work in their fields.

Graduates and researchers who show exceptional promise are selected for advanced training. After studying for three years

and preparing a dissertation, they are awarded a "candidate" degree, roughly comparable to our Ph.D. The Soviets already have more science "candidates" than we have Ph.D.'s in science. This, however, may be misleading since the quality of the post-graduate work may not always be on a par with our own. As I mentioned previously, the educational system is not geared to original thinking and the dissertations may in many cases not involve as original research as is required in this country. The Soviets do recognize this fact and are making efforts to overcome the difficulty.

Scientific Achievements

Scientific achievements vary from field to field. In areas important to national power and military strength the Soviets excel. For example, their work in combustion phenomena and chemical kinetics is probably the finest in the world, and they are highly competent in low temperature physics research.

They have recently announced the existence of a number of high speed electronic digital computers. The largest of these, the BESM, is comparable to some of the better high speed computers in the United States and U.K., although not quite so good as a recently completed U.S. computer. Nesmeyanov, President of the USSR Academy of Sciences, has announced that high speed computer research is one of a number of areas of fundamental importance in which the Soviets will concentrate their efforts as, he stated, research in this field is likely to lead to a scientific breakthrough.

During the past year, the Soviets have demonstrated competence in many aspects of nuclear research. For example, they have reported on the construction of a 10 Bev proton synchrotron, the largest such accelerator in the world. This machine, which will be in operation shortly, was actually inspected by a number of American and Foreign scientists on their recent visit to Moscow for a conference. There seems no question that this is a competently engineered device and will open to the Soviets during the next few years facilities for fundamental physics research which cannot be duplicated anywhere. The U. S. and European laboratories are designing and constructing accelerators in the 30 Bev range which are due for completion in 1960 or 1961, but on the other hand, the Soviets are now planning a larger accelerator up to 50 Bev. When one considers that this 10 Bev synchrotron will require some 36,000 tons of steel, about equivalent to that required for one large battleship, and when one realizes that this machine will not directly lead to any developments of military or economic value, it becomes obvious that the Soviet leaders have a real appreciation for the value of fundamental scientific research. On the other hand, despite their appreciation of the need for elaborate equipment for

such research, their reported research programs using this equipment have not necessarily been outstanding. This Spring, Ve[illegible] and other Soviet scientists attended a conference on high energy particle physics at Rochester and reported on work they had accomplished in this field. These accomplishments, while indicating competence, did not demonstrate any outstanding abilities or originality and indicated a failure to exploit the available facilities.

Since the Geneva conference last summer, the Soviets have published considerable material on their atomic reactor program. The research reactors which they have described appear soundly designed but apparently do not incorporate any radically new approaches which have not been carefully considered in this country. They have at least in public statements placed considerable emphasis on atomic power and boasted that their small power reactor outside Moscow was the first in the world to produce useful power. Furthermore, the Academician Kurchatov has announced a number of details of the Soviet Five Year Plan for producing nuclear electric power. This program calls for some 2 to 2½ million kilowatts of electric power installed by the end of 1960. This is truly an ambitious and expensive goal in terms of both manpower and raw materials and the soundness of this approach to future economic nuclear power can be questioned. Kurchatov has indicated, however, that a

number of different types of large reactors will be included in such a program so that the Soviets can get information which will be useful for future developments. This program would appear to be another example of the Soviet attempt to advance on a key problem by mass use of the scientific and engineering manpower. At a recent conference on reactor development in Moscow, almost 1000 persons were in attendance indicating broad scientific interest in this subject. On the other hand, here again their program and reported developments do not indicate any great brilliance or originality.

In order to exploit foreign scientific advances, the Soviets have an extensive information gathering program and are rapidly working to perfect a comprehensive system for disseminating these data. Their abstracting service is a "State matter" and is accomplished primarily by ministerial offices and the USSR Academy of Sciences. The Academy's Institute of Scientific Information gives very thorough coverage of the world's scientific literature. In 1956, the Institute will sponsor publication of 12 series of abstract journals. It is estimated that one year's production of the series will compare in size to about 33 volumes of the Soviet Encyclopedia (slightly larger than 33 volumes of the Britannica). Not only is the abstracting service large, but it is quick. We know of instances in which abstracts of United States articles have appeared in Soviet abstract journals before they appeared in United States abstract journals. Perfection of this dissemination program will undoubtedly save time and expense in

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